Extragalactic Star Clusters
IAU Symposium Series, Vol. Vol. 207, 2001
Eva K. Grebel, Doug Geisler, and Dante Minniti, eds.

Spectroscopy of Globular Clusters in NGC 1399 - A Progress Report

T. Richtler, B. Dirsch, D. Geisler

Grupo de Astronomía, Departamento de Física, Universidad de Concepción, Casilla 160-C, Concepción, Chile

K. Gebhardt

Department of Astronomy, University of Texas at Austin, USA

M. Hilker, L. Infante, D. Minniti, M. Rejkuba

Departamento de Astronomía y Astrofísica, P. Universidad Católica, Vicuña Mackenna 4860, Santiago 22, Chile

J. C. Forte

Facultad de Ciencias Astronomicas y Geofísicas, Universidad Nacional de La Plata, 1900 La Plata, Argentina

S. Larsen

Lick Observatory, University of California at Santa Cruz, USA

E. K. Grebel

MPI für Astronomie, Königstuhl 17, D-69117, Heidelberg, Germany

V. Alonso

Observatorio astronomico Cordoba, Laprida 854, 5000 Cordoba, Argentina

Abstract. We performed spectroscopy of globular clusters associated with NGC 1399 and measured radial velocities of more than 400 clusters, the largest sample ever obtained for dynamical studies. In this progress report, we present the sample and the first preliminary results. Red and blue clusters have slightly different velocity dispersions in accordance with their different density profiles. Their velocity dispersions remain constant with radial distance, which differs from earlier work.

1. Introduction

We performed spectroscopy of globular clusters in NGC 1399, the central cD-galaxy in the Fornax cluster, with a double intention: firstly, we want to use globular clusters as probes of the gravitational potential of this galaxy and secondly,

we want to investigate whether there are kinematical differences among subpopulations of clusters with different metallicities. Both X-ray analyses (Jones et al. 1997, Ikebe et al. 1996) and previous studies of globular cluster velocities (Grillmair et al. 1994, Kissler-Patig et al. 1999) indicated that NGC 1399 should possess a massive dark matter halo. However, the sizes of earlier samples of cluster velocities were too small to allow a definitive dynamical analysis. We therefore aimed at obtaining enough radial velocities to determine both the potential of the galaxy and the phase space distribution of clusters. In this contribution, we report on our progress in this project and present the first preliminary results.

2. Observations and Data Analysis

We pre-selected cluster candidates by photometry in Washington C and Cousins R of MOSAIC data from the 4m telescope at CTIO (see Dirsch et al. 2001, these proceedings). Our candidates cover a magnitude range of $20 < R < 23$ and a color range of $0.7 <$ C-R < 2.2. An additional criterion was the "stellarity"-index returned by SExtractor to discriminate against background galaxies. As the radial velocities later on showed, the success rate of selecting clusters and not stars or galaxies, was very high, about 95 %. The spectroscopic observations have been performed in the period 30.11-2.12.2000 at the VLT (Kuyen) with FORS2 and the Mask Exchange Unit (MXU). The grism was 600B, giving a spectral resolution of about 2.5 Å, based on the widths of the arc lines. The spectral range which could be used was 3800 to 6000 Å, depending on the slit position in the mask and the signal-to-noise. To be flexible with respect to the object selection, we decided to set sky slits independently from the objects slits. For most of the slits, the size was $1 \times 2''$. The number of slits on a mask varied between 100 and 120. We exposed 13 masks (exposure times were either 45 min or 2×45 min) and obtained spectra of about 500 cluster candidates and many miscellaneous objects like point sources outside our color and magnitude limits and galaxies, as well as hundreds of sky spectra at varying galactocentric radii. The range of radial distances from the galaxy center was $2' < R < 8'$, corresponding to 11 kpc $< R <$ 44 kpc with an adopted distance of 19 Mpc. The extraction of the spectra was done with "apextract" under IRAF. The wavelength calibration was very accurate, so that subtracting an independently calibrated sky from an object worked well. Small zeropoint differences of the order 0.5 Å between the masks were adjusted by matching the sky lines.

We measured radial velocities by cross-correlating a suitable part of the spectrum with a template spectrum, which we chose to be that of NGC 1396. In general the interval 4500 - 5500 Å gave the highest correlation peaks. The errors, which were returned by the correlation software ("fxcor" under IRAF), varied between 10 km/s for our brightest objects and more than 100 km/s for the faintest ones (when a reasonable correlation peak could be found). We verified that these errors are indeed resonable by comparing those objects which were found in two different masks (about 25).

We excluded objects with velocity errors larger than 100 km/s. Moreover, we excluded a few cluster candidates with radial velocities smaller than 500 km/s and larger than 2500 km/s. After that our sample now consists of 369 clusters.

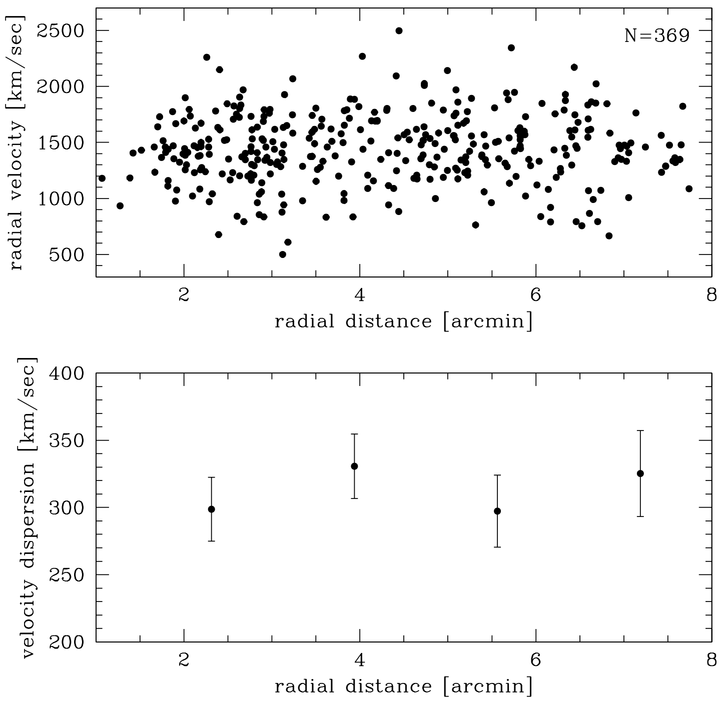

Figure 1. The upper panel shows the error-selected (< 100 km/s) and velocity-selected (500 km/s $< v_r <$ 2500 km/s) sample of globular cluster velocities. In the lower panel we plot the measured velocity dispersions in four radial bins. We do not see an increase of the velocity dispersion with radius, which contrasts with earlier work.

The final sample will have more than 400. We expect that many miscellaneous stellar-like objects will still turn out to be globular clusters, but we already now have the largest sample ever obtained for a dynamical analysis of a globular cluster system.

3. Preliminary Results

Fig. 1 shows in the upper panel the entire sample of 369 velocities vs. the angular galactocentric distance in arcmin.

The measured (projected) velocity dispersion of the entire sample is 310 ± 20 km/s. The lower panel gives the dispersions in four radial bins. It remains constant within the errors over the whole radial range (at this moment, the dispersion is simply calculated as the dispersion of a Gaussian and has not been estimated with more sophisticated statistical tools). This is in disagreement with earlier work (Kissler-Patig et al. 1999) which suggested a considerable increase between $2'$ and $6'$.

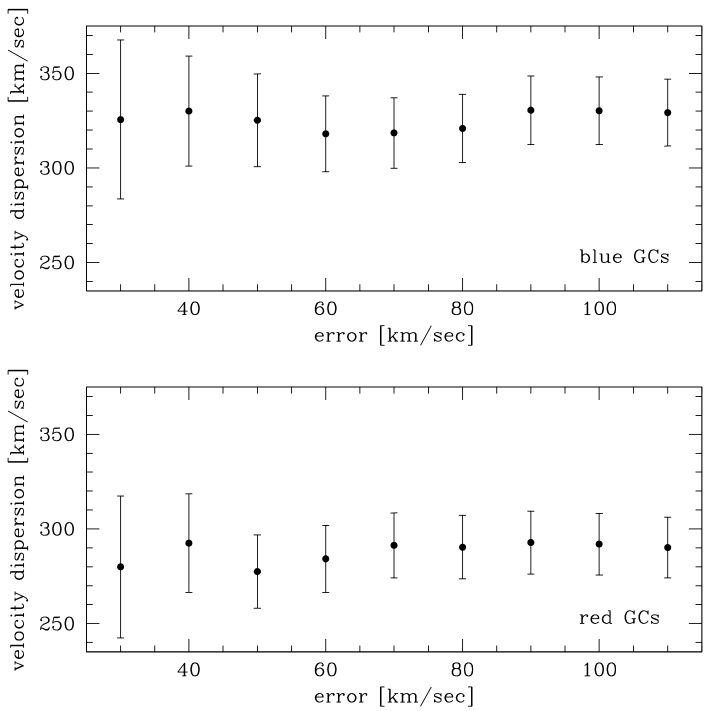

Figure 2. The ordinate gives the velocity dispersion of the error selected samples of red and blues clusters, respectively. The abcissa is the maximum error which was allowed to calculate the respective dispersion. This plot demonstrates that the difference between the velocity dispersions of the red and the blue clusters stays if we select clusters with progressively smaller velocity errors.

In the bimodal color distribution of clusters (see Dirsch et al. 2001, these proceedings), we use a color of $\mathrm{C-R} = 1.4$ to separate the metal-poor from the metal-rich clusters. The metal-poor (190 objects) and the metal-rich (179 objects) subsamples show slightly different velocity dispersions of 330 ± 18 km/s and 291 ± 16 km/s, respectively, and again do not indicate a change with radial distance. These values decrease insignificantly to 326 ± 18 and 286 ± 16, if we subtract the contribution of our mean error of 50 km/s to the velocity dispersion.

Fig.2 shows the mean dispersions for the blue and the red clusters and that their difference remains stable if we select objects with progressively smaller velocity errors.

We do not see any significant rotation for most of the cluster population except perhaps for the outer metal-poor clusters, for which a marginal rotation signature might be present.

The dynamical analysis, in which we intend to apply axisymmetric, three-integral models (Gebhardt et al. 2000) will supersede the following exercise. As a first approach, we assume spherical symmetry (NGC 1399 is slightly elliptical)

and neglect rotation. Then the radial Jeans-equation reads

$$\frac{G \cdot M(r)}{r} = -\sigma_r^2 \cdot (\frac{d \ln \rho}{d \ln r} + \frac{d \ln \sigma_r}{d \ln r} + 2\beta)$$

where G is the constant of gravitation, r the galactocentric distance, M(r) the mass contained within r, σ_r the radial component of the velocity dispersion, ρ(r) the density profile of clusters, $\beta = 1 - \frac{\sigma_\Theta^2}{\sigma_r^2}$ with σ_Θ being the tangential velocity dispersion. Unless β is large, a radially constant *projected* velocity dispersion implies a constant σ_r and $\frac{d\ ln\sigma_r}{d\ ln\ r} = 0$. Within our radial range, the red and the blue clusters show different density profiles (Dirsch et al. 2001, these proceedings), $\frac{d\ ln\rho}{d\ ln\ r} \sim$ -2.5±0.1 and -1.8±0.1, respectively. They must trace the same mass, so it is interesting that the difference of the density profiles could account completely for the difference in the velocity dispersions, if β would be zero.

A handy formula for the mass inside a radius r is ($\beta = 0$)

$$M[M_\odot] = 2 \cdot 10^{10} \cdot r[kpc] \cdot (\frac{\sigma_r^2}{300km/s})^2 \cdot \alpha$$

where α is the slope of ρ(r) and where a distance of 19 Mpc has been assumed. The mass inside 10 kpc is $4.2 \cdot 10^{11} M_\odot$ and thus inside 40 kpc $1.7 \cdot 10^{12} M_\odot$, which is in good agreement with the values given by Jones et al. (1997) and somewhat higher than the values found in Ikebe et al. (1996), who moreover find a shallower dependence of M(r) than M(r) $\sim$ r.

A radially constant σ_r and thus a constant circular velocity is an interesting analogy to disk galaxies. NGC 1399 is an example of a spheroidal galaxy, where a dark halo and luminous component might "conspire" to show a constant circular velocity. Since this is the first time that the dynamical analysis can be performed out to 4 effective radii, one can expect to further constrain the properties of the dark halo.

4. Reference List

Dirsch B, Geisler D., Richtler T., Forte J.C. 2001, these proceedings
Gebhardt K. et al. 2000, AJ, 119, 1157
Grillmair, C. et al. 1994, ApJ, 422, L9
Ikebe, Y. et al. 1996, Nature, 379, 427
Jones, C. et al. 1997, ApJ 482, 143
Kissler-Patig M. et al. 1999, AJ, 117, 1206